Section 5.0 Integration of Best Management Practices

As the preceding sections have illustrated, Best Management Practices (BMP) are seldom employed singly. Furthermore, it is virtually impossible for some BMPs to be employed without the use of other integral and complementary BMPs. For example, if regrading of dead spoils is performed, corresponding revegetation would also be needed; partial underground mine daylighting requires sealing of undisturbed mine entries at the final highwall; and daylighting commonly entails the cleanup of acid-forming materials surrounding the remaining pillars, which in turn need to be special handled. The efficiency of many BMPs can be augmented by employing others which complement them. The ability of regrading of dead spoils to preclude surface water infiltration can be improved when combined with diversion ditches, lined channels, stream sealing, or spoil capping. The efficacy of special materials handling of acid-forming materials can be aided by special water handling facilities and alkaline addition.

Past mining practices, prior to the initiation of the Surface Mining Control and Reclamation Act (SMCRA), dealt mainly with extracting coal as inexpensively as possible. Little attention was paid to the environmental impacts of the active operation, much less the condition of the site after mining was completed. The need for employing multiple BMPs is driven by site characteristics such as the condition and amount of prior land disturbance, acidity of overburden, and the extent of abandoned deep mines, and by requirements to prevent further degradation by taking additional, pollutional countermeasures. These abandoned mines often require multiple BMPs to effect adequate reclamation and pollution mitigation.

There are two basic mechanisms by which BMPs work to decrease the contaminant load: 1) by physically decreasing the flow of the discharge, and 2) by geochemically improving the water quality (decrease the contaminant concentration). Some BMPs perform both functions to varying degrees simultaneously. Sealing of deep mine entries will inhibit the flow of ground water as well as prevent the infiltration of oxygen into the mine. Revegetation will inhibit water and oxygen infiltration into the backfill as well as impede erosion and sedimentation. It can also increase the amount of CO_2 available in spoil and therefore can positively influence carbonate dissolution. The choice of which BMPs are needed to decrease the pollutant loads is site-specific and cannot be determined using cookbook methodology. The experience and knowledge of permit preparers and reviewers are the major factors in the successful selection, design, and implementation of remining BMPs.

Some of the BMP combinations have been discussed in preceding sections. This section will discuss these combinations in more detail, as well as cover BMP combinations not previously discussed. This section was written to cover the benefits of combining BMPs. It is not the intention of this section to discuss the benefits of all possible BMP combinations, but rather to discuss the overall benefits of combining BMPs. It is likely that there are some beneficial combinations not specifically addressed.

Regrading and Revegetation

Regrading and revegetation work hand-in-hand to decrease pollution loadings both physically and geochemically. This BMP combination functions physically by reducing the amount of surface water introduced into the backfill and, geochemically by altering spoil pore gas composition that impacts the weathering of carbonates and pyrite. Spoil regrading eliminates exposed, highly permeable material and closed contour depressions, both of which, when unchecked, facilitate direct infiltration into the spoil of surface water, and promote surface runoff.

The addition of soil and vegetative cover over regraded spoil also works to enhance the inhibition of surface water infiltration. Soils will allow some surface water infiltration, but a great deal of the infiltrating water will be held in the soil horizon until it is used by plants. The structure of soil cover is such that significant quantities of water are preferentially retained. The soil holds water near the ground surface which permits direct evaporation. The addition of vegetative cover further inhibits water infiltration into the underlying spoil. The plants, during the growing season, will take up the water in the soil and transpire it back into the atmosphere. Certain types of plants will promote additional runoff, especially during high intensity precipitation events. Use of biosolids can greatly enhance the vegetative growth and cover percentage, which in turn, will promote greater water use by the plants. However, biosolids should be applied with the provision that the nutrients that they provide may promote significant growth of iron-oxidizing bacteria, thus possibly increasing acid production. However, this effect may be transient and relatively insignificant (Cravotta, 1998). The application of biosolids in Pennsylvania's Remining Site Study appears to have resulted in a positive influence on water quality (Section 6, Table 6.3a).

The more stable regraded surfaces will also function geochemically by inhibiting the introduction of oxygen at depth and by retaining carbon dioxide. Regrading of several spoil piles into one large backfilled area results in less surface area and fewer slopes for atmospheric exchange. In addition, thicker spoil will make it more difficult for oxygen penetration at depth. Soil cover and plant growth tend to further preclude oxygen infiltration and retention of carbon dioxide in the underlying spoil. In addition, the decay of organic matter in the soil utilizes oxygen, further suppressing deeper oxygen infiltration.

Combining implementation of diversion ditches and stream sealing above the mined area and/or across the surface of the backfill (typically implemented on sites with severely acidic overburden) can augment the efficiency of regrading and revegetation. Capping the site with a low permeability material can also reduce surface water as well as oxygen infiltration.

There are cases where regrading and revegetation alone are not adequate for pollution reduction. If the regraded spoil is determined to be inherently acidic and the acid-forming materials are widely disseminated, other BMPs such as alkaline addition, mining into alkaline strata (if present), or alkaline redistribution may be necessary. Another BMP that has been used in these circumstances is the installation of induced alkaline recharge structures.

Daylighting

There are several BMPs that can be implemented in conjunction with daylighting to enhance the impact on discharge pollution loadings. Daylighting commonly generates considerable acid-forming materials (waste coal, immediate roof rock, etc.) when the area around pillars is cleaned prior to the excavation of the coal. This acidic material generally requires special handling to further prevent AMD formation. If the amount of acid-forming materials removed from around the coal pillars is significant, this material may need to be removed from the site and disposed of off-site. Additionally, because of the fair amount of acid-forming material that is usually spoiled, alkaline addition may be needed to offset the acidity potential. The alkaline material may also require special handling. Depending on the situation, alkaline material may need to be placed either above the acidic material to prevent AMD formation, or below or within the acidic material to neutralize AMD already formed. Alternatively, mining may need to progress to a predefined overburden thickness to allow disturbance of significant quantities of naturally occurring alkaline rocks above the coal.

If the daylighting does not eliminate all of the abandoned underground mine, other BMPs may be used to aid pollution abatement. The mine entries will need to be sealed to exclude the lateral infiltration or discharge of ground water as described in Section 1.0. Mine entry seals also inhibit the infiltration of atmospheric oxygen to or from the underground mine. If considerable water is stored in and is flowing through the underground mine, a drain may need to be piped from behind the seals through the backfill, thus diverting the water away from the site.

Coal Refuse Removal

Coal refuse removal or reprocessing is a special case of remining. The acidic material is partially or completely removed from the site. In either coal refuse removal or reprocessing, the potential for AMD production is greatly reduced, because the sulfur source is diminished.

Other BMPs can also be employed to further the pollution abatement. In cases where the coal is reprocessed on-site and the waste rock is returned, bactericides may be an option to inhibit pyrite oxidation prior to covering and revegetating the pile. Bactericides can be applied as the waste material is transported via a conveyor belt. Sites involving coal refuse removal or reprocessing are also prime candidates for alkaline addition. Coal refuse seldom has any natural alkalinity-producing ability, therefore any alkaline material added should be beneficial in AMD prevention or neutralization.

Prior to remining, coal refuse piles commonly allow considerable water and oxygen infiltration. These piles are poorly vegetated and typically do not promote runoff. Regrading, soiling and revegetation of the waste material will prove beneficial in many respects, not the least of which is to promoting runoff and reducing water and oxygen infiltration. Surface water control structures (e.g., diversion ditches) and the capping of the refuse with a low permeability material can also aid the reduction of pollution loads.

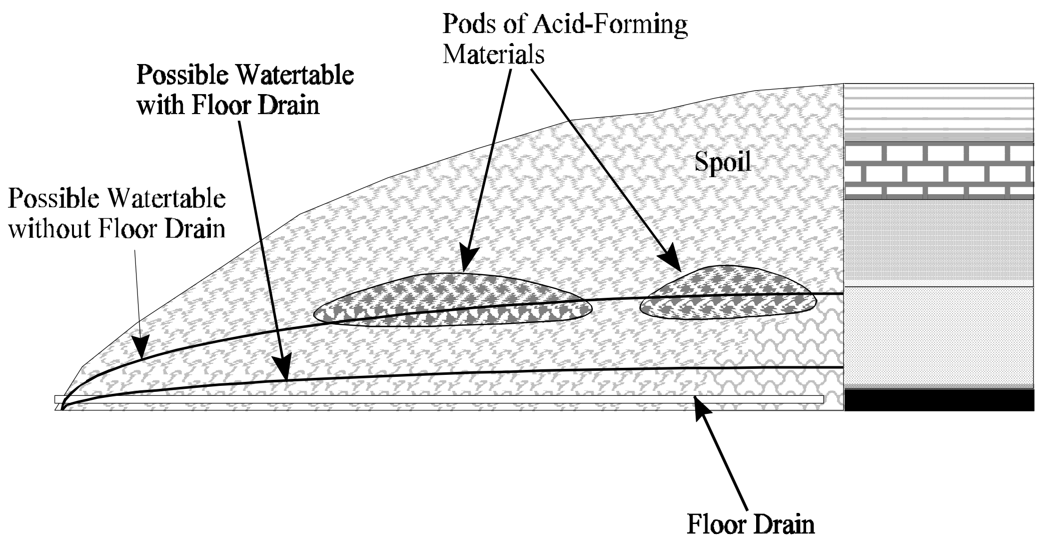
Remining operations involving complete removal of the coal refuse will nearly completely eliminate the AMD production. However, all of the refuse is seldom removed. Refuse is screened and the fine material, which contains most of the coal, is sent to the power plant. The larger materials remain behind. There are usually minor amounts of refuse left in place. Other BMPs that can prove useful with these types of operations are alkaline addition, regrading and revegetation, and surface water control. Coal combustion waste (CCW), a byproduct of burning the refuse, is often returned to these sites. CCWs typically contain some alkaline material resulting from the addition of limestone during the burning process, thus providing some acid-neutralization potential.

Special Handling with Surface and Ground-Water Controls

A critical component of successful special handling of acidic and alkaline material is understanding the ground-water system. If the ground water can be controlled, special handling will more likely prove successful.

In cases where the acidic material is placed in pods in the backfill and are intended to be located above the fluctuating water table, ground-water control and, to some extent, surface water control can be used to suppress the water table and dampen water table fluctuations. Highwall drains and highwall diversion wells can be employed to intercept laterally infiltrating ground water, and floor drains can be used to collect and rapidly remove ground water. Both of these BMPs will work to suppress the water table (Figure 5.0a). Mine entry sealing and diversion (piping or channeling) of underground mine waters will also aid in this respect. The use of surface water diversion ditches, spoil capping, and/or stream sealing will aid in suppressing the water table through reduced vertical infiltration. Capping and revegetation may aid geochemically by inhibiting atmospheric oxygen infiltration into acidic pods, reducing pyrite oxidation, and reducing the amount of water available for transport of acid materials.

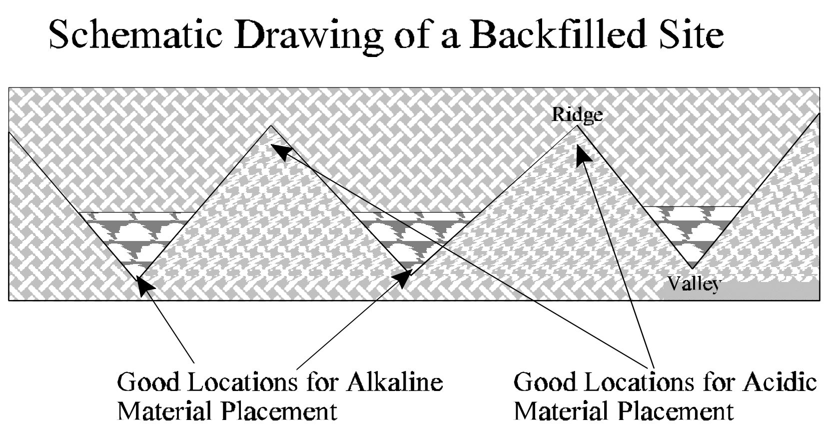
Figure 5.0a: Water Table Suppression in Conjunction with Special Handling of Acidic Material



Conversely, if alkaline material is specially handled within the backfill, it may be beneficial to divert extra water through these areas to generate additional alkalinity. This is similar to induced alkaline recharge (Section 2.3). In cases of special handling of alkaline materials, there are ground- and surface-water controls that can be employed to increase the amount of water that encounters the alkaline material. Chimney drains can be used to funnel water from the surface toward alkaline zones. Additionally, the drains themselves can be comprised of limestone or other alkaline rock. The surface of the reclaimed site can be configured to promote selective infiltration. Small impoundment areas can be created to allow surface water to collect and infiltrate in areas above alkaline-rich areas.

Alkaline material can be placed in areas that will be within the main ground-water flow paths. Ground water will flow primarily along the path of least resistance, which in mine spoil is commonly the buried spoil valleys. The larger spoil particles tend to roll off the sides and collect at the valleys between spoil piles. Thus, these valleys tend to be highly transmissive zones that facilitate significant ground-water flow (Hawkins, 1998). Placing alkaline material in these valleys, prior to reclamation, will likely enhance increased alkalinity production. Conversely, the acid-rich pods would be best placed in the center of the ridges as far away, both vertically and horizontally, from the highly transmissive zones as possible, but such that they will not be too near the surface. These optimal placement locations are illustrated in Figure 5.0b.

Figure 5.0b: Optimal Location for Special Handling of Acidic and Alkaline Materials



For selected sites where acidic material placement is below the water table, the use of water infiltration control BMPs can be beneficial. It is critical to keep this acidic material under saturated conditions and out of contact with atmospheric oxygen. Given the hydrogeologic conditions within the Appalachian Plateau, many surface mines are located above the regional water table and local water tables are relatively thin. Keeping acidic material under saturated conditions is extremely difficult. However, if large amounts of water can be induced to infiltrate into and held within spoil, it can help maintain a minimum water level in the backfill. Chimney drains and induced alkaline recharge structures can be used to promote infiltration. In addition, the surface of the reclaimed site can be configured to promote direct infiltration, and small impoundment areas can be created to allow surface water to collect and infiltrate into the spoil. Engineered highwalls can also be created to aid infiltration. For example, bench slopes can be designed to induce infiltration by directing water back toward the highwall, permitting small impoundments or infiltration zones rather than promoting runoff. Once ground water has infiltrated the backfill, as much ground water as possible should be stored to maintain a high water table and saturated conditions. Surface mining below the regional ground-water flow system should allow acidic material submergence, because the water table will commonly re-establish itself and be maintained at a sufficient level. Because it is common in the Appalachian Plateau for undisturbed strata to have hydraulic conductivity values two orders of magnitude lower than the associated spoil (Hawkins, 1995), if the final highwall is down dip from the mining operations, substantial ground water should impound behind it. In these situations, acidic material should be placed against the highwall to maximize the potential for continual submergence. If the highwall is up dip of the mining operations or the strata are nearly level, maintaining a high water table will be extremely difficult, because the ground water will tend to drain more freely at the toe of the spoil. Therefore, subaqueous placement of acidic materials will likely not be an option. If hydrologic controls (e.g., low permeability zones) can be installed in the backfill to inhibit ground-water movement and subsequent discharge, subaqueous placement of acid-forming materials may be viable through maintenance of an elevated water table. A thorough knowledge of site hydrogeologic conditions is required to attempt a “dark and deep” placement or saturated condition of acid-forming materials. However, even with these ground-water controls, a protracted drought may cause the water table to drop below the level of the acidic material, which will likely make worsen the water qualitiy.

Alkaline addition also can be combined with the use of low permeability CCW. CCW, when used as a capping, entry seal, or grouting material, can be used with other BMPs to inhibit water movement and provide the ground water with some alkalinity. CCW also can be beneficial when applied to acidic pit floors by sealing the pit floor from ground water.

Miscellaneous BMP Combinations

The use of passive treatment systems can be beneficial to virtually all remining sites with continuing post-remining AMD discharges, regardless of the BMPs employed during mining. However, some types of passive treatment can be integrated into the reclamation plan. These passive treatment systems include installing an ALD as a pit floor underdrain through the backfill and configuring the regrading and revegetation to create a wetland.

Mining into enough cover to encounter alkaline strata can also be beneficial for special handling of acidic materials. Acidic materials, when strategically placed above the water table, commonly need to be well above the pit floor (e.g., >15 to 20 feet) and deep enough to be removed from the impacts of infiltrating atmospheric oxygen. Therefore, a substantially thick backfill is required to maintain the acid-forming materials within these narrow guidelines. Mining into additional cover may yield the necessary spoil thickness to properly handle acid-forming materials.

Capping of mine spoil with a low permeability material can aid the alkalinity production of inherent, redistributed, and added alkaline materials in the backfill. These caps can inhibit the exchange of gases from the backfill to the atmosphere and vice versa. Therefore, the caps will prevent CO_2 in the vadose zone from escaping, which will promote higher alkalinity production.

Summary

BMPs are seldom employed alone. Because of the frequently multifaceted nature of abandoned surface and underground mines, BMP combinations are required to enhance reclamation and to preclude the potential for greater pollution loadings due to remining. Some BMPs, when used in conjunction with others can enhance the pollution load reduction efficacy.

This section does not cover all potential BMP combinations, but does review some of the more common combinations being implemented during remining operations. BMP plans do not lend themselves to a preset methodology or cookbook formula. Each remining operation requires a BMP plan that stems from site-specific conditions that are contingent on the background and experience of the remining permit and BMP plan preparer and reviewer. Factors such as the extent of previous mining, configuration of the abandoned site, geochemistry of the overburden, site hydrology, and topography all impact the formulation of an effective BMP plan.

References

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